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Surface and Groundwater Calculations for the MuCool Beam Absorber

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(May 2004)

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Introduction

MuCool is part of a research project for studying single pass muon beam transverse cooling using a liquid hydrogen target[1]. For this phase of the project a proton beam will be used instead of a muon beam. The MuCool facility is being built as an extension of the 400MeV LINAC. The proton beam after passing through liquid hydrogen will end up on a beam absorber.

This note describes the calculations to investigate the concentrations of radioisotopes ^{22}Na and tritium that may reach the surface waters and the aquifer. Details of the methodology used are given in the references and will not be repeated here.

Methodology

Figure 1 shows a longitudinal cross section of the proposed beam absorber. Figure 2 shows the results of the MARS Monte Carlo[2,] modeling of the proton beam interactions with the absorber and the resulting radiation levels outside the absorber. Radiation leaking outside the absorber will produce several radioisotopes in the soil. ^{22}Na and tritium are the most important ones, where water contamination is considered.

The Concentration Model [3,4,5] was used to predict the concentrations of the ^{22}Na and tritium in the water right outside the enclosure. A groundwater contaminant transport method[6-8] was used to estimate the attenuation of the radionuclide concentrations during transport to the aquifer.

Results

Figure 3 shows the results of the geological characterization in the MuCool area. The aquifer is 12.75m below the absorber. It is assumed that the abort is somewhere in the fill region, above the 728 ft elevation.

Figures 4a and 4b show that the maximum tritium produced from five years of continuous operations will take about 120 years to get to 6.5m-7m depths. Figure 4c shows the results of a 10-year operation period. Calculations showed, because of radioactive decay, that even after 500 years tritium activity does not move deeper than 10m. For the same reason, the ^{22}Na will never get further than 2.5m. Based on these calculations the radionuclides will be attenuated by at least a factor of 10^8.

Table 1 shows the results of this calculation for different proton intensities per year. For 10^{21} protons/year the surface water limit will be exceeded. To avoid the surface water issue, it is planned to bury this absorber in the soil with no granular fill under-drain. The porous section of under-drain for the nearby building in this region will also be replaced with solid pipe and backfilled with clay or lean concrete[9].

Conclusion

Provisions to bury the absorber in the soil and assuring there is no discharge of water from around the beam absorber to the surface waters will mitigate the surface water issue. Given the low seepage velocity and the large attenuation of the contaminants through the soil, the ground water limit will not be approached for the projected proton intensities.

References

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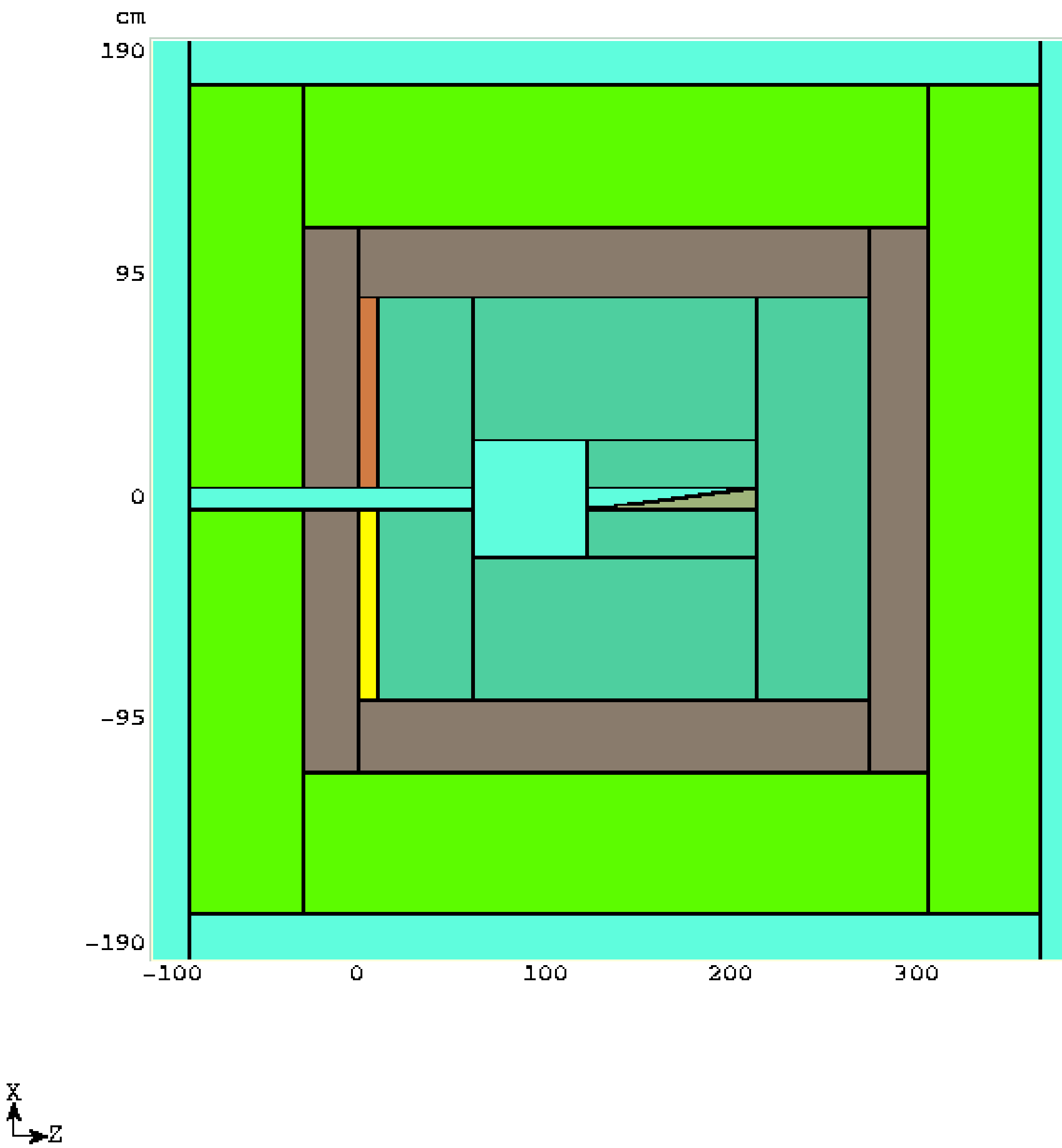


Figure 1. A longitudinal cross section of the beam absorber. The central angled piece is the copper core (brown), surrounded by iron (dark green), concrete shell (gray), soil (light green) and air (light blue). The cavity in the absorber is designed to trap neutrons, to reduce backscatter, and to reduce dose rates in the experimental area.

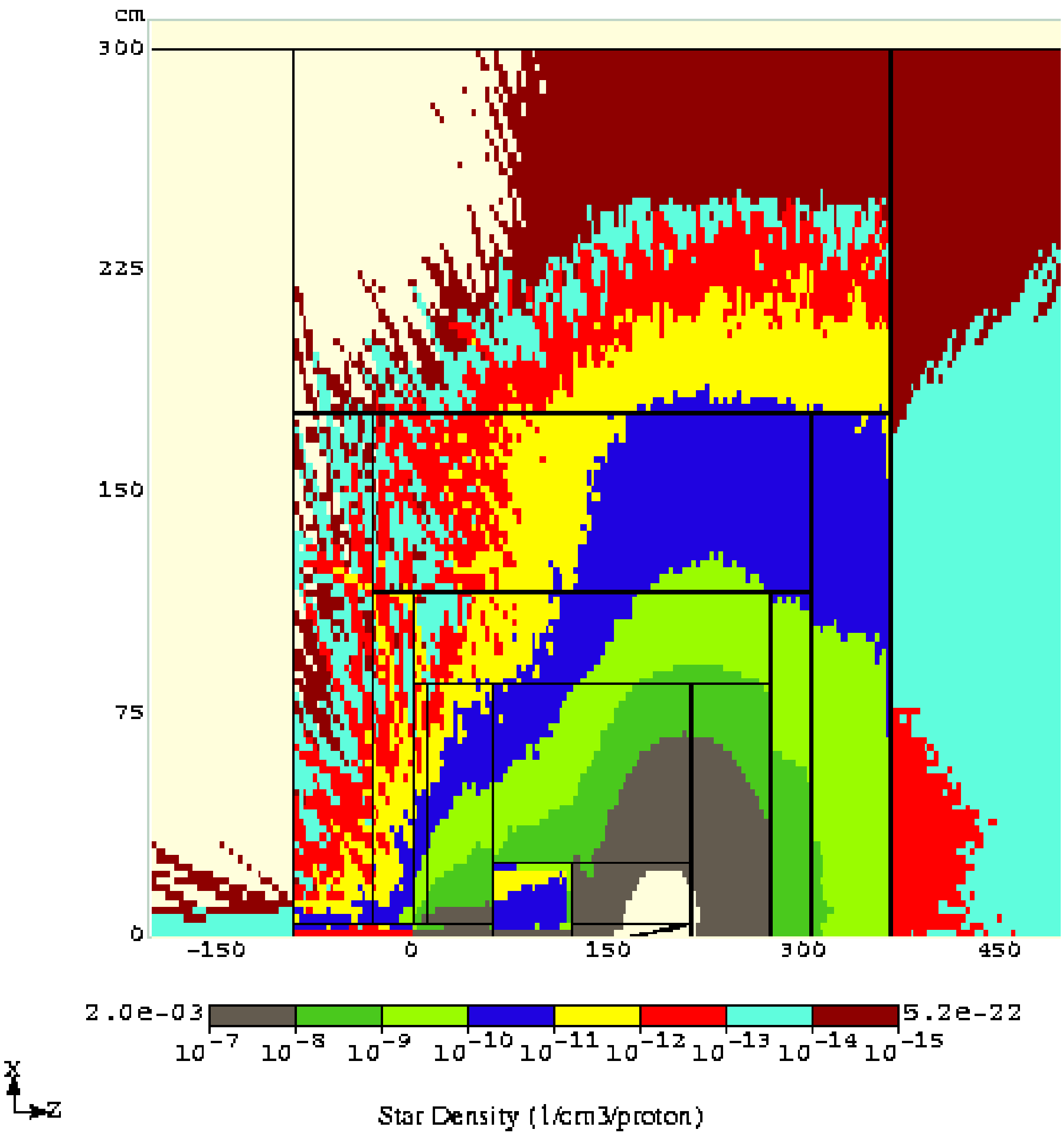
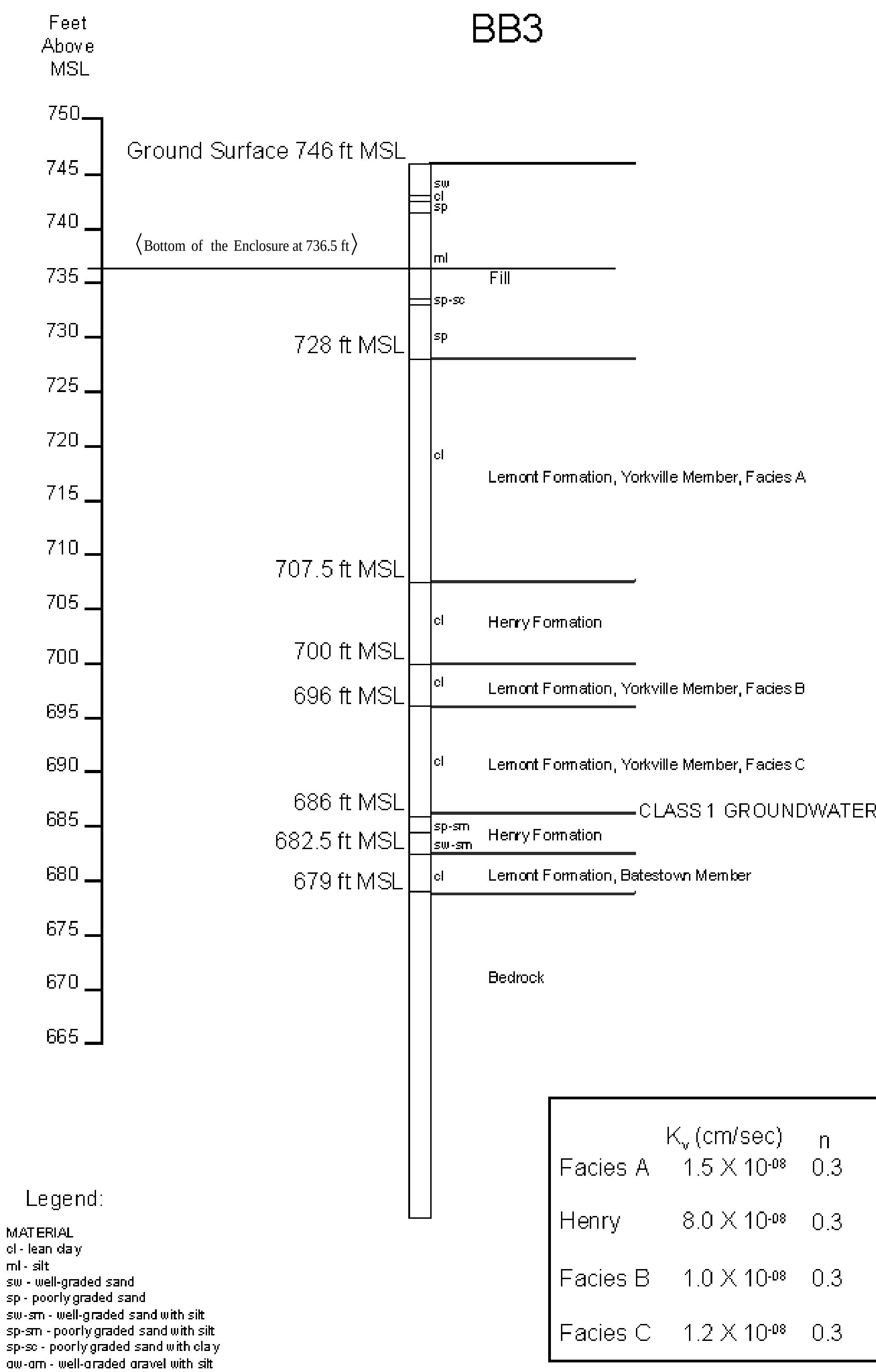
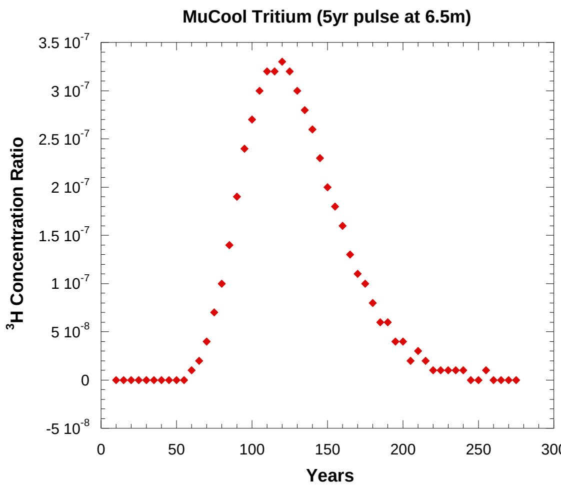


Figure 2. MARS calculations showing the star density distribution in and around the beam absorber.

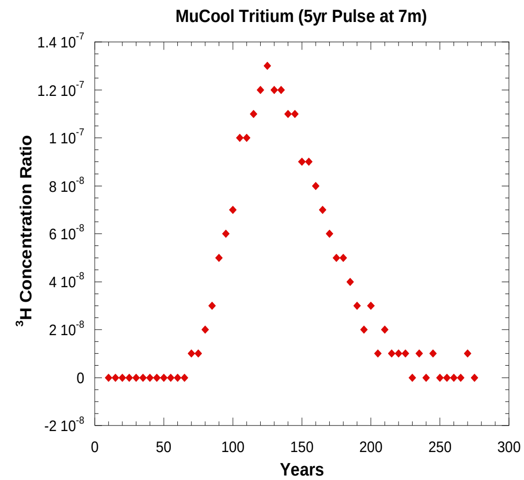


	K_v (cm/sec)	n	i	t (cm)
Facies A	1.5×10^{-08}	0.3	-0.40	625
Henry	8.0×10^{-08}	0.3	-0.40	230
Facies B	1.0×10^{-08}	0.3	-0.80	120
Facies C	1.2×10^{-08}	0.3	-1.00	300

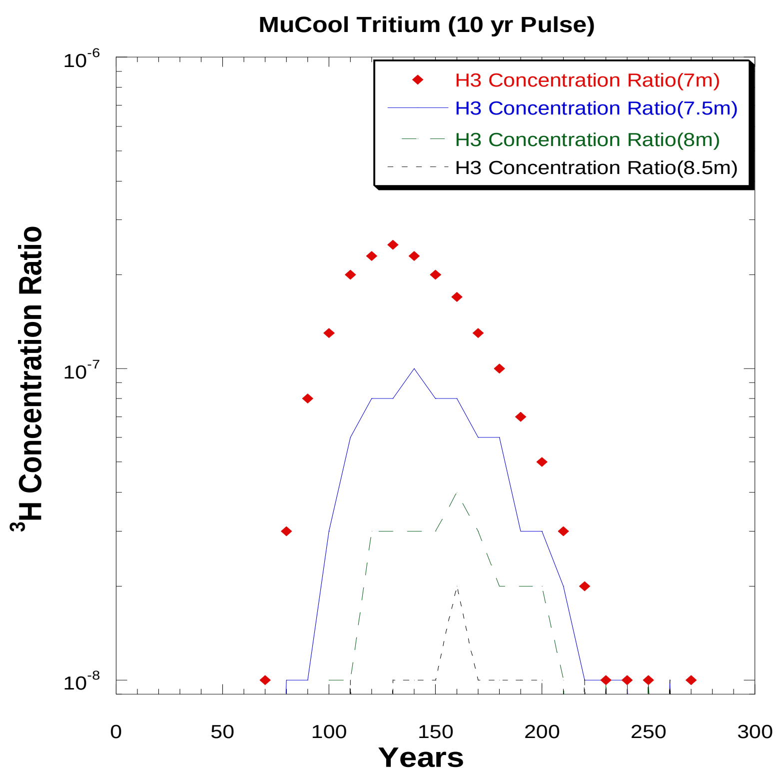
Figure 3. Geological characteristics of the ground in the beam absorber area.



(a)



(b)



(c)

Figure 4. Results of the contaminant transport calculations. (a) and (b) show the transport of the peak contaminant concentration of tritium from 5years of operation at 6.5m and 7m depths. Figure (c) shows the number of years required for the peak activity of a 10-year operation to get to different depths.

			R(Till)= **1.00E-08**					
S-ave= **2.7E-11**		stars/cc/p	T-irr (yr) = **1**					
			T-cool (yr) = **0**					
	Tritium			Sodium			% of Total Limit	
Protons/year	C-initial (pCi/cc-y)	C-final (pCi/cc-y)		C-initial (pCi/cc-y)	C-final (pCi/cc-y)		Surface	Aquifer
1.00E+19	1	1.38E-08		0	1.23E-09		1.3%	0.00%
1.00E+20	14	1.38E-07		1	1.23E-08		13.0%	0.00%
1.00E+21	138	1.38E-06		12	1.23E-07		**129.677%**	0.00%
1.00E+22	1382	1.38E-05		123	1.23E-06		**1296.8%**	0.00%
1.00E+23	13817	1.38E-04		1228	1.23E-05		**12967.7%**	0.00%
1.00E+24	138173	1.38E-03		12277	1.23E-04		**129677.2%**	0.04%

Table 1. Concentration model calculations for different proton intensities. The gray C01 columns give the concentration of each radionuclide right outside the concrete, and C(t)f1 Columns give the expected concentration in the aquifer. The right two columns combine concentrations as a percentage of the allowed regulatory limits.